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Inventors: Kent R. Struble, Duane A. Preszler
Customer No. 01333

APPARATUS AND METHOD FOR THERMALLY PROCESSING AN IMAGING MATERIAL EMPLOYING A PREHEAT CHAMBER

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APPARATUS AND METHOD FOR THERMALLY PROCESSING AN IMAGING MATERIAL EMPLOYING A PREHEAT CHAMBER

FIELD OF THE INVENTION

The present invention relates generally to an apparatus and method for processing an imaging material, and more specifically to an apparatus and method for thermally developing an imaging material employing a preheat chamber.

BACKGROUND OF THE INVENTION

Light sensitive photothermographic or heat sensitive film typically includes a thin polymer or paper base coated, generally on one side, with an emulsion of dry silver or other heat sensitive material. Such photothermographic film is normally processed or developed at a temperature generally in the vicinity of 120 degrees centigrade. To produce a high quality image, controlling heat transfer to the photothermographic film during the development process is critical. If heat transfer is not uniform during development, visual artifacts such as non-uniform density and streaking may occur. If heat is transferred too quickly, the base of some types of photothermographic film can expand too rapidly, resulting in expansion wrinkles that can cause visual artifacts in a developed image.

Several processing machines have been developed in efforts to achieve optimal heat transfer to the photothermographic film during processing. One employs a heated drum with multiple rollers around the exterior of the drum's circumference to press the film against the drum. This technique is typically best suited for film having an emulsion coating on only one side, as more heat is generally transferred to the side of the film facing the drum as compared to the side opposite the drum. Another machine slides the photothermographic film over flat heated surfaces in a horizontal path or over plates arranged in a circular path. Still another machine is a flat-path processor having rollers above and below the film to transport the film through the processor.

The processors in each of these machines heats the photothermographic film to a processing temperature and maintains the film at the

processing temperature for a set time for optimal development. One processor includes a preheat zone that rapidly heats the film to the development temperature to initiate the development process, and a dwell zone that keeps the film at the development temperature for the set time to complete development.

While such processors are effective at developing photothermographic films prepared using polymeric binders coated from organic solvents, they are not as well-suited for processing newly emerging gelatin-based photothermographic films. These films are coated from aqueous-based solvents, contain heat sensitive materials such as developers, and require a higher development temperature. The moisture content of these aqueous-based emulsions can affect the heat transfer characteristics of the film and, consequently, the quality of images produced during processing. The moisture level of these emulsions is also susceptible to changes depending on the temperature and humidity of the environment in which they are stored and used. Consequently, the moisture level of the emulsion can vary between films. This can result in film-to-film variations in image quality after processing.

It is evident that there is a need for a photothermographic film processor capable of uniformly developing gelatin-based photothermographic film without introducing visual artifacts as described above.

SUMMARY OF THE INVENTION

In one embodiment, the present invention provides a preheat chamber for conditioning an imaging material having a conditioning threshold temperature and a developing threshold temperature. The preheat chamber includes a chamber housing and a heating system, the heating system is configured to heat the imaging material to a desired conditioning temperature above the conditioning threshold temperature and below the developing threshold temperature as the imaging material is moved through the chamber housing.

In one embodiment, the present invention provides a thermal processor for thermally developing an image in an imaging material having a conditioning threshold temperature and a developing threshold temperature. The thermal processor includes a preheat chamber and a dwell chamber. The preheat

chamber is configured to receive the imaging material at an ambient temperature and to heat the imaging material to a desired conditioning temperature at least equal to the conditioning threshold temperature but less than the development threshold temperature. The dwell chamber is configured to receive the imaging material at the conditioning temperature and to heat the imaging material to a desired developing temperature at least equal to the developing threshold temperature.

In one embodiment, the imaging material includes an aqueous-based emulsion including heat sensitive materials and having a moisture level, wherein a temperature level at least equal to the conditioning threshold temperature causes moisture to be released from the aqueous-based emulsion, and a temperature level at least equal to the development temperature causes the image to develop. In one embodiment, the preheat chamber is configured to maintain the imaging material at the conditioning temperature for a time period necessary to cause substantially all of the moisture to be released from the emulsion.

By removing substantially all of the moisture from the aqueous-based emulsion of the imaging material prior to development, the present invention minimizes the potential of post-development visual artifacts due to excessive moisture levels and minimizes the potential for variations in image quality from film-to-film. Also, heating the imaging material to a desired conditioning temperature prior to heating the imaging material to a desired developing temperature reduces the potential of visual artifacts related to expansion of a base material of the imaging material.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are better understood with reference to the following drawings. The elements of the drawings are not necessarily to scale relative to each other. Like reference numerals designate corresponding similar parts.

FIG. 1 is a block diagram illustrating one exemplary embodiment of a thermal processor according to the present invention.

FIG. 2 is a block diagram illustrating one exemplary embodiment of a thermal processor according to the present invention.

FIG. 3 is a graph illustrating temperature and moisture levels of a suitable gelatin-based photothermographic film during processing by the thermal processor of FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

Figure 1 is a block diagram illustrating generally one embodiment of a thermal processor 30 in accordance with the present invention for developing an image in an imaging material 32 having a conditioning threshold temperature and a development threshold temperature.

An example of a thermally processable imaging material suitable for development by thermal processor 30 is the gelatin- or aqueous-based photothermographic imaging film disclosed in pending U.S. Patent Application Serial Number 10/715,199, filed on November 17, 2003, commonly assigned, and incorporated herein by reference (Attorney Docket No. 86093/JLT).

One type of gelatin-based photothermographic imaging material suitable for development by thermal processor 30 comprises a base material coated on each side with an aqueous-based emulsion of heat sensitive materials, including developers, in an aqueous-based solvent. When heated to a temperature at or above a conditioning threshold temperature, fluid, consisting primarily of water, is released in vaporous form from the emulsion, leaving the heat sensitive materials on the imaging material. When subsequently heated to a temperature at or above a development threshold temperature, the heat sensitive materials react to form an image on the imaging material.

Thermal processor 30 includes a preheat chamber 34 and a dwell chamber 36 that is thermally isolated from preheat chamber 34. Preheat chamber 34 includes a housing 38, having an entrance 40 and an exit 42, enclosing a transport system 44 and a heating system 46. Dwell chamber 36 includes a

housing 48, having an entrance 50 and an exit 52, enclosing a transport system 54 and a heating system 56.

Preheat chamber 34 receives imaging material 32 at an ambient temperature and with the emulsion having an arbitrary moisture level at entrance 40. Transport system 44 moves imaging material 32 through preheat chamber 34 along a transport path 58 from entrance 40 to exit 42. As imaging material 32 moves through preheat chamber 34, heating system 46 heats imaging material 32 to a desired conditioning temperature at least equal to the imaging material's preconditioning threshold temperature but less than the development threshold temperature.

In one embodiment, the desired conditioning temperature is within a conditioning temperature range. The low end of the range is at a margin above the conditioning threshold temperature, and the high end of the range is a margin below the development threshold temperature to ensure that desired conditioning temperature is high enough to cause the water/moisture to be released from the emulsion but low enough to prevent the heat sensitive developing compounds from reacting and developing the image. In one embodiment, the conditioning temperature is within a range from 110 to 130 degrees centigrade (°C), with a desired conditioning temperature of 120 °C.

As the temperature of imaging material 32 exceeds the conditioning threshold temperature and reaches the desired conditioning temperature, water begins to be released from the aqueous-based emulsion in the form of water vapor. Preheat chamber 34 maintains the imaging material at the conditioning temperature for a conditioning period at least long enough for substantially all of the water/moisture to be released from the emulsion. In one embodiment, the conditioning period is within a time range. In a preferred embodiment, preheat chamber 34 maintains imaging material 32 at a conditioning temperature of 120°C for a conditioning period of 5 seconds.

In one embodiment, transport system 44 moves imaging material 32 through preheat chamber 34 at a rate such that imaging material 32 is maintained at the desired conditioning temperature for the conditioning period. In this embodiment, transport system 44 receives imaging material 32 at the ambient

temperature at entrance 40, moves imaging material 32 along transport path 58, and provides imaging material 32 at exit 42 at substantially the conditioning temperature and with substantially all of the water/moisture released from the emulsion. In one embodiment, transport system 44 moves imaging material 32 through preheat chamber 34 at a rate within a range of 0.4-to-0.5 inches per second. It is noted, however, that the rate at which transport system 44 moves imaging material 32 is dependent on the conditioning period and a length of preheat chamber 34.

Dwell chamber 36 receives imaging material 32 from preheat chamber 34 at entrance 50, with imaging material 32 at a temperature substantially equal to the conditioning temperature and with substantially all of the water/moisture released from the emulsion. Transport system 54 moves imaging material 32 through dwell chamber 36 along transport path 58 in proximity to heating system 56 from entrance 50 to exit 52.

As imaging material 32 through dwell chamber 36, heating system 56 heats imaging material 32 from the preconditioning temperature to a development temperature at least equal to the development threshold temperature. In one embodiment, the development temperature is within a development temperature range. In one embodiment, the development temperature range is from 135° C to 165° C, and in a preferred embodiment the development temperature is 150° C.

Dwell chamber 36 maintains imaging material 32 at the development temperature for a development period that will provide substantially optimal development of the image in imaging material 32. In one embodiment, the development period is within a time range. In one embodiment, the development period ranges from 18 to 25 seconds. In a preferred embodiment, dwell chamber 36 maintains imaging material 32 at a development temperature of 150°C for a development period of 20 seconds.

In one embodiment, transport system 54 moves imaging material 32 through dwell chamber 36 at a rate such that imaging material 32 is maintained at the desired conditioning temperature for conditioning period. In this embodiment, transport system 44 receives imaging material 32 at the ambient

temperature at entrance 40, moves imaging material 32 along transport path 58, and provides imaging material 32 at exit 42 at substantially the conditioning temperature and with substantially all of the water/moisture released from the emulsion.

One characteristic of gelatin-based photothermographic imaging material is that the moisture level, or the amount of water, in the aqueous-based emulsion can change depending on the film's local operating environment, with humidity being the primary factor. Essentially, the aqueous-based emulsion is somewhat sponge-like and can absorb water from the surrounding air. Because humidity varies from location to location and can vary over time at a given location, the moisture level of the emulsion can vary from film to film at the time of development. Furthermore, since the amount of water in the aqueous-based emulsion affects the film's heat transfer characteristics (i.e., the more water the more heat that must be transferred to heat the film to a desired temperature), the varying moisture levels can potentially result in undesirable variations in image quality from film-to-film. For example, excessive moisture levels can result in streaking or variations in development density of developed images.

By substantially removing all of the moisture from the aqueous-based emulsion of imaging material 32 at preheat chamber 34 prior to providing imaging material 32 to dwell chamber 36 for development, thermal processor 30 minimizes the potential of visual artifacts due to excessive moisture levels and minimizes the potential for variations in image quality from film to film. Furthermore, by heating imaging material 32 to the conditioning temperature prior to its entering dwell chamber 36, dwell chamber 36 needs to raise the temperature of imaging material 32 to the developing temperature from the conditioning temperature rather than the ambient temperature, thereby reducing visual artifacts caused by expansion of the base material.

When rollers and heat plates are spaced along a horizontal transport path, a thermal processor can be referred to as a flatbed-type processor. (For example, as further described below with reference to Figure 2, thermal processor 30 according to the present invention can be referred to as a flatbed-type processor wherein rollers 70, 72 and heat plates 78 of preheat chamber 34, and rollers 96, 98

and heat plates 104 are spaced adjacent to and along horizontal transport path 58.) Another type of thermal processor can be referred to as a drum-type processor which, as the name implies, employs a heated drum around which a photothermographic film is at least partially wrapped and heated during a developing process. An additional and unexpected benefit provided by thermal processor 30 in the development of gelatin-based photothermographic imaging film is an improvement in the film's "Dmin Gain" relative to such film developed using a drum-type thermal processor. Dmin Gain is a test to determine how well a film ages. More specifically, Dmin is a minimum density of an image after development as generally known to one skilled in the art.

Figure 2 is a cross-sectional view illustrating one exemplary embodiment of thermal processor 30 according to the present invention, including preheat chamber 34 and dwell chamber 36. Transport system 44 includes a plurality of upper rollers 70 and a plurality of lower rollers 72. Heating system 46 includes an upper heating member 74 and a lower heating member 76, with each heating member including a heat plate 78 and a corresponding heat blanket 80.

Rollers 70 and 72 can include support shafts 82 having cylindrical sleeves of support material 84 surrounding the external surface of shafts 72. Support shafts 72 are rotatably mounted to opposite sides of enclosure 38 in a spaced relationship along transport path 58 between entrance 40 and exit 42, such that support material 74 contacts imaging material 32.

One or more of the rollers 70, 72 can be driven in order to drive imaging material 32 through preheat chamber 34 adjacent to the heating plates of heating members 74, 76 along transport path 58. In one preferred embodiment, all of the rollers 70, 72 are driven so that the surface of each roller is heated uniformly when no imaging material is contacting rollers 70, 72. In one embodiment, rollers 70, 72 are driven at a rotational speed such that imaging material 32 is maintained at a desired conditioning temperature for a desired conditioning period before exiting preheat chamber 34 at exit 42.

As illustrated, upper roller 70 can be positioned relative to lower rollers 72 to cause imaging material 32 to be bent or curved in an undulating fashion when transported between rollers 70, 72. Creating these curvatures can be

accomplished, as shown, by horizontally offsetting upper rollers 70 from lower rollers 72 and vertically positioning them such that the upper rollers 70 and lower rollers 72 overlap a horizontal transport path 58. Curving imaging material 32 in this fashion increases a column stiffness of imaging material 32 and enables imaging material 32 to be transported through and heated to a conditioning temperature within preheat chamber 34 without a need for nip rollers or other pressure transporting means. Consequently, thermally-induced wrinkles of imaging material 32 associated with "nipping" or pressure can be minimized.

Upper rollers 70 can be sufficiently spaced apart, as can lower rollers 72, so that imaging material 32 can expand with minimal constraint in the direction generally perpendicular to transport path 58. This minimizes the potential for formation of significant wrinkles across imaging material, generally perpendicular to the direction of transport path 58. Furthermore, the minimization of these wrinkles can be accomplished without requiring that imaging material 32 be under tension when transported through preheat chamber 34. This is particularly important when developing imaging material 32 of relatively short lengths.

Heating system 46 includes an upper heating member 74 and a lower heating member 76. Heating members 74, 76 each include a heat plate 78 and, as illustrated, can be heated with a corresponding heat blanket 80. In one embodiment, heat plates 78 can be aluminum. Heat plates 78 associated with heating members 74, 76 can be configured with multiple zones with the temperature of each zone individually controlled, for example, by a controller (not shown) and a temperature sensor 86 corresponding to each zone, such as a resistance temperature device or a thermocouple.

Likewise, heat blankets 80 can be configured with multiple zones, with each zone corresponding to one of the heat plate zones and providing a temperature based on temperature sensor 86 of the corresponding heat plate zone. Additionally, the zones of heat blankets 80 can be configured with varying watt densities, such that one heat blanket zone may be capable of delivering more thermal energy to its corresponding heat plate zone relative to another heat blanket zone. Since different heat plate zones, depending upon their location within

preheat chamber 34, may transfer more thermal energy to imaging material 32 than other heat plate zones, zonal control of heat blankets 80 is beneficial in maintaining imaging material 32 at an even temperature.

In one embodiment, as illustrated, heat plates 78 are shaped to partially wrap around a portion of the circumference of rollers 70, 72 such that rollers 70, 72. By partially nesting rollers 70, 72 within heat plates 78 in this fashion, heating members 74 and 76 can more effectively maintain the temperature of the outer surfaces of rollers 70, 72, resulting in their providing a more uniform heat transfer to imaging material 32.

By positioning heating members 74, 76 proximate to each side of transport path 58, each side of imaging material 32 is heated as it passes through preheat chamber 34. Furthermore, by providing zoned control of heat members 74, 76, the temperature across the surfaces of heat plates 78 can be more uniformly controlled and heat may be more evenly transferred to imaging material as it passes through preheat chamber 34. For example, if imaging material 32 has a width less than that of heat plates 78, the middle portions of heat plates 78 will transfer more heat to the imaging material and, thus, lose heat faster than the edge portions. In this instance, heat blankets 80 can be controlled so as to provide more heat to those zones corresponding to the central portions of heat plates 78.

As a result, water from the aqueous-based emulsion of imaging material 32 will be more evenly out-gassed from the surfaces of imaging material 32, thereby reducing the potential for visual artifacts in the developed image due to uneven moisture levels in the emulsion. Also, by transporting imaging material 32 through preheat chamber 34 on upper rollers 70 and lower rollers 72 proximate to, but without contacting heat plates 78, each side of imaging material 32 is able to freely outgas water vapor from the aqueous-based emulsion.

In one embodiment, as illustrated, preheat chamber 34 includes an evacuation system that includes exhaust ports 88 and 90 that are configured to couple to an external vacuum system 91. External vacuum system 91 is configured to draw air from preheat chamber 34 to thereby exhaust air and substantially all water vapor and other byproducts released from the aqueous-based emulsion of imaging material 32 from preheat chamber 34. In one

embodiment, the exhaust air is filtered after removal from preheat chamber 34. In one embodiment, the evacuation system is configured such that external vacuum system 91 draws external air into preheat chamber 34 via entrance 40 and exit 42. Entrance 40 and exit 42 can be flow restricted or sealed, and the evacuation system configured to include passages or channels through heat plates 78 through which external vacuum system 91 draws external air so that the external air is heated prior to entering preheat chamber 34 to thereby better maintain the temperature of imaging material 32 at a desired conditioning temperature.

In one embodiment, as illustrated, thermal processor 30 includes a transition section 92 positioned between preheat chamber 34 and dwell chamber 36. Transition section 92 includes a guide channel 94 configured to guide imaging material 32 from exit 42 of preheat chamber 34 to entrance 50 of dwell chamber 36. In one embodiment, exit 42 of preheat chamber 34 and entrance 50 to dwell chamber 36 include seals to substantially maintain thermal isolation between preheat chamber 34 and dwell chamber 36.

As illustrated, dwell chamber 36 can be configured in a fashion similar to preheat chamber 34, with transport system 54 including a plurality of upper rollers 96 and a plurality of lower rollers 98. Likewise, heating system 56 includes an upper heating member 100 and a lower heating member 102, with each heating member including a heat plate 104 and a corresponding heating blanket 106. In one embodiment, dwell chamber 36 can be similar to the dwell chamber disclosed in U.S. Patent No. 5,869,806, which is herein incorporated by reference.

One or more of the rollers 96, 98 can be driven so as to move imaging material 32 through dwell chamber 36 along transport path 58 adjacent to heating members 100, 102. In one embodiment, rollers 100, 102 are driven at a rotational speed such that imaging material 32 is heated from the conditioning temperature to the developing temperature and held at the developing temperature for a desired developing period as it is transported through dwell chamber 36 from entrance 50 to exit 52. In one preferred embodiment, the rotational speed of rollers 96, 98 of dwell chamber 36 substantially match the rotational speed of rollers 70, 72 of preheat chamber 34.

Heating members 100, 102 can be zoned in a fashion similar to that of heating members 74, 76 of preheat chamber 34, with the temperature of each zone being individually controlled based on a temperature sensor 108 corresponding to each zone. By zoning heating members 100, 102, heat can be more uniformly transferred to imaging material 32. For instance, zones adjacent to entrance 50 lose heat to imaging material 32 more quickly than zones adjacent to exit 52. Therefore, those zones adjacent to entrance 50 can be controlled so as to provide more heat than those zones adjacent to exit 52.

In one embodiment, as illustrated, dwell chamber 36 includes an evacuation system that includes exhaust ports 110 and 112 that are configured to couple to external vacuum system 91. External vacuum system is configured to draw air from dwell chamber 36 through exhaust ports 110 and 112 in order to exhaust gaseous byproducts released by imaging material 32 during development. In one embodiment, the exhaust air is filtered after removal from preheat chamber 34. In one embodiment, the evacuation system is configured such that the external vacuum system 91 draws external air into dwell chamber 36 via entrance 50 and exit 52. Entrance 50 and exit 52 can be flow restricted or sealed, and the evacuation system configured to include passages or channels through heat plates 104 through which external vacuum system 91 draws external air is so that the external air is heated prior to entering dwell chamber 36 to thereby better maintain the temperature of imaging material 32 at a desired conditioning temperature.

In one embodiment, thermal processor 30 includes a receiver section 114. Receiver section 114 includes a pair of nip rollers 116 configured to receive imaging material 32 at an ambient temperature and to feed imaging material to transport system 44 of preheat chamber 34 via entrance 40.

Figure 3 is a graph 120 illustrating the temperature and moisture levels of gelatin-based imaging material 32 as it travels through thermal processor 30 as illustrated by Figure 2. Temperature and moisture levels are illustrated along the y-axis, as indicated respectively at 122a and 122b, and a distance traveled through thermal processor 30 is illustrated along the x-axis as indicated at 124. Graph 120 includes zones representative of the sections/chambers of thermal processor 30, with a zone 126 representative of receiver section 114, a zone 128

representative of preheat chamber 34, a zone 130 representative of transition section 92, and a zone 132 representative of dwell chamber 36. Waveforms 134 and 136 respectively represent the temperature and moisture level of imaging material 32.

As imaging material 32 enters receiver section 114, it is at an ambient temperature level as indicated at 138. After entering preheat chamber 34, the temperature of imaging material begins to rise, as indicated at 140, until the temperature of the imaging material reaches the desired conditioning temperature, as indicated at 142. The temperature of imaging material 32 is maintained at the desired conditioning temperature by preheat chamber 34 until it enters transition section 92, where the temperature may drop slightly as indicated at 144. After entering dwell chamber 36, the temperature of imaging material 32 rises, as indicated at 146, until the temperature reaches the desired developing temperature, as indicated at 148. Dwell chamber 36 maintains the temperature of imaging material 32 at the desired developing temperature until imaging material exits the dwell chamber 36, as indicated at 150.

As illustrated by waveform 136, imaging material 32 has an arbitrary moisture level as it enters and travels through receiver section 114, as indicated at 152. As imaging material 32 enters preheat chamber 34 and the its temperature begins to rise, its moisture level begins to drop, as indicated at 154. As the temperature of imaging material 32 rises to the desired conditioning temperature at 142, the removal of moisture from the aqueous-based emulsion accelerates, as indicated at 156, until the moisture level drops to substantially zero, as indicated at 158. The moisture level remains at near-zero levels as it travels through transition section 92 and dwell chamber 36, as indicated at 160.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. This application is intended to cover any adaptations or variations of the specific embodiments discussed herein. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.

PARTS LIST

30	Thermal Processor
32	Imaging Material
34	Preheat Chamber
36	Dwell Chamber
38	Preheat Chamber Housing
40	Preheat Chamber Entrance
42	Preheat Chamber Exit
44	Preheat Chamber Transport System
46	Preheat Chamber Heating System
48	Dwell Chamber Housing
50	Dwell Chamber Entrance
52	Dwell Chamber Exit
54	Dwell Chamber Transport System
56	Dwell Chamber Heating System
58	Transport Path
70	Preheat Chamber Upper Rollers
72	Preheat Chamber Lower Rollers
74	Preheat Chamber Upper Heating Member
76	Preheat Chamber Lower Heating Member
78	Preheat Chamber Heat Plates
80	Preheat Chamber Heat Blankets
82	Preheat Chamber Roller Support Shafts
84	Preheat Chamber Roller Support Material
86	Preheat Chamber Temperature Sensor
88	Preheat Chamber Exhaust Port
90	Preheat Chamber Exhaust Port
91	External Vacuum System
92	Transition Section
94	Guide Channel
96	Dwell Chamber Upper Rollers
98	Dwell Chamber Lower Rollers

100 Dwell Chamber Upper Heating Member
102 Dwell Chamber Lower Heating Member
104 Dwell Chamber Heat Plates
106 Dwell Chamber Heat Blankets
108 Dwell Chamber Temperature Sensor
110 Dwell Chamber Exhaust Port
112 Dwell Chamber Exhaust Port
114 Receiver Section
116 Nip Rollers